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REDUCTION OF HELICOPTER PARASITE DRAG

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SUMMARY

A reduction in helicopter parasite drag is possible but not profitable except in those cases where high speed and long range are primary requirements. For some of the factors causing drag, reduction in parasite-drag area may result in increased weight whereas, in other cases, it does not. The final design, however, must be a compromise between the reduction of drag and the increase in weight.

INTRODUCTION

In the past, there has been little consideration given to the problem of helicopter parasite drag. Many more serious problems such as vibration, stability, and even adequate hovering performance have required the full attention of the designer. In any event, parasite drag becomes important only in the higher speed range.

Now, however, there are certain uses of the helicopter where high speed and long range are important. Wherever this is the case, it appears that significant benefits can be realized from reductions in parasite drag. The purpose of this paper is to indicate the order of magnitude of these possible benefits and to discuss a few of the ways by which parasite drag can be reduced.

SYMBOLS

f	equivalent parasite-drag area
Ω	rotor angular velocity
R	blade radius
σ	solidity
Δf	increment of parasite-drag area
S	disk area

EFFECT OF PARASITE DRAG ON PERFORMANCE

In order to illustrate the effect of certain parasite-drag reductions, a theoretical performance analysis has been made for a single-rotor helicopter having a gross weight of 10,000 pounds, a solidity of 0.07, a tip speed of 500 feet per second, and a disk loading of 2.5 pounds per square foot. Figure 1 shows the variation of main-rotor horsepower required with velocity for three assumed values of equivalent parasite-drag area (refs. 1 and 2). A value of 40 square feet was chosen as representative of current practice for helicopters of this size. This value represents a ratio of disk area to parasite-drag area S/f of 100. The discontinuities in the curves occur at the velocity where tip stall begins on the retreating blade (ref. 3).

The lower curve for $f = 0$ square feet (fig. 1) represents the minimum power required by the rotor. Obviously, zero parasite drag can never be achieved. However, the area between the top curve and the bottom curve (fig. 1) indicates the total power saving theoretically possible from reduction of parasite drag. In a practical case, it might not be unreasonable to expect that the parasite drag could be reduced 50 percent. The center curve (fig. 1) for a parasite area of 20 square feet indicates the power savings which could be realized from such a 50-percent reduction in parasite drag.

In this particular case, there would be no reason to reduce the drag of the helicopter if it were going to operate below about 40 miles per hour because all the curves practically coincide at and below this velocity. For low-speed operation, higher parasite drag might be acceptable because of simplicity of design and fabrication.

However, for the type of operation where speed and range are of primary importance, a reduction in drag will result in large savings. For instance, if the power available is assumed to be equal to the hovering power, the top speed of this helicopter could be increased 19 miles per hour by a 50-percent reduction in drag. This drag reduction would also result in a 25-percent increase in maximum range and the speed for best range would be increased 11 miles per hour.

MEANS OF REDUCING PARASITE DRAG

Now, consider a few methods by which the parasite drag may be reduced. There is, of course, extensive literature on this subject, based largely on airplane-drag-cleanup investigations in the Langley full-scale tunnel. Some of these studies, including a couple of fairly complete summaries, are given in references 4 to 10. No effort is made

herein to give a complete review of the subject but only a few basic items are considered. The landing gear, the rotor hub, the engine-exhaust stacks, the cooling losses, and air leakage through joints and gaps in the fuselage are considered. The location and shape of cooling-air exits, fuselage shape, and the location of external protuberances on the surface of the fuselage are also discussed. The savings in parasite drag for these factors are given in the following table:

Item	Δf , sq ft
Landing gear	20.0
Rotor hub	1.2
Exhaust stacks6
Cooling	1.6
Leakage	1.6
Cooling-air exits	----
Fuselage shape	----
Protuberances	----
Total	25.0

Landing-gear installation.- Shown in figure 2 are sketches of the landing-gear installations on three different helicopters in the general weight range which is being considered. Past experience with airplanes indicated that the landing gear contributed from one-third to one-half the total drag. Calculations of the parasite drag of helicopter landing gears such as these indicate a parasite-drag area of about 20 square feet. When available drag data for wheels, struts, and tubing are used, a parasite-drag area of 15 square feet is obtained if no interference losses are considered. Experience indicates that the interference drag of the various strut intersections, the strut-fuselage intersection, and the wheel-strut intersection would probably add at least another 5 square feet and thus give a total area of 20 square feet. All this drag increment could be saved by use of a fully retractable landing gear. In some cases it may be impractical or undesirable to retract the gear fully. In that event, significant drag reductions, possibly equal to the sum of all these other items, may still be realized by proper fairing of the wheels and struts. Some data on landing-gear fairings are presented in references 5 and 6. It should be mentioned that there will probably be some weight penalty involved in retracting or fairing the gear. This weight increase would somewhat reduce the estimated power saving.

Rotor hub.- The full extent to which the drag of the rotor hub can be reduced by proper fairing is not known at present. However, some very limited data on the rotor-hub drag of a general research model are

available. The upper sketch of figure 3 shows the original unfaired hub and supporting pylon of the model. The lower sketch of figure 3 shows the fairing which was installed on the hub. Results of the investigation indicate that the parasite-drag area of the helicopter could be reduced 1.2 square feet by the installation of a simple fairing of the type shown. This particular fairing was an ellipsoid of revolution having a fineness ratio of approximately 3.5 to 1.

Engine exhaust stacks.- Two typical radial-engine exhaust-stack installations are shown as figure 4. An increment of 0.93 square foot was measured for the large stovepipe type of installation shown in figure 4. As can be seen, it protrudes from the aircraft nearly normal to the airstream and has excessive form drag in spite of the attempted fairing at the base of the stack. Another installation on an engine of similar power and having the exhaust stacks flush with the surface of the fuselage (fig. 4) produced a drag increment of only 0.31 square foot. In this case, the form drag of the stacks was virtually eliminated, and the measured drag was probably caused by air leakage around the stacks. In this case, a saving of 0.6 square foot was obtained. Examination of several helicopter exhaust-stack installations indicates that even more substantial drag reductions than those obtained herein might be realized by careful detail design.

Cooling-air system.- The discussion on the cooling-air system is based on an analysis for the piston engine installation made by John R. Henry of the Langley laboratory. As shown in that analysis, if the cooling air loses full free-stream dynamic pressure in the inlet, there will be a large parasite drag chargeable to the cooling system. This condition probably exists in most helicopter cooling installations. Calculations assuming complete loss of free-stream dynamic pressure but for an airtight duct system indicate a parasite area of 1.6 square feet for the helicopter flying at 100 miles per hour. This source of drag could be eliminated by designing the cooling system so that the free-stream dynamic pressure is recovered.

At this time, it might also be well to mention that the cooling-air exits should be designed so that the cooling air leaves the body parallel to the external flow. If the cooling air does not exit smoothly, it may disturb the flow over the fuselage and cause premature separation. This separation would result in an additional drag increment over and above that which would be theoretically predicted from the internal losses.

Leakage of air through gaps and joints.- Leakage of air through unsealed gaps and joints, that is, all the gaps and joints, in the fuselage structure may also be a source of much parasite drag. Leakage drag is an item which is dependent to a great extent on the detail design and care in manufacture of the aircraft and is rather difficult to estimate without access to the particular helicopter. However, an estimate based on the average leakage drag of several World War II fighter aircraft indicates that at least 1.6 square feet could be saved

if the helicopter were sealed. Sealing is far from standard practice at the present time.

Fuselage shape and external protuberances.- The effect of fuselage shape and external protuberances on the parasite-drag area is next considered. It is obvious that helicopter fuselages, in general, are not very streamlined; however, the helicopter fuselage may present some special problems. There may be some compromise necessary to insure that the stability and low-speed performance are not unduly penalized in the process of streamlining for high speed. Unfortunately, no explicit data which would indicate the specific areas of high drag on existing shapes are available. Although these data are lacking, it is felt that the general rules of good streamlining should be used as a guide.

One thing specifically, however, might be emphasized; that is the desirability of not locating external fittings and protuberances in regions of local high-velocity flow. Their drag will be increased because of the high local dynamic pressure and it is not unlikely that the air flow will be disturbed sufficiently to cause separation either locally or further downstream on the body.

CONCLUDING REMARKS

In conclusion, it might be said that a significant reduction in helicopter parasite drag is possible. However, reduction in drag becomes important only when high speed and long range are primary requirements. An estimate of the possible savings shows a reduction of 25 square feet of parasite-drag area for the factors considered. All these savings may not be possible, however, because there may be some weight penalty involved for such cases as a retractable landing gear or a rotor-hub fairing. The added weight would reduce the estimated power saving somewhat. In this regard, it should be pointed out that the drag of some of the smaller items such as exhaust stacks, cooling, and leakage probably can be eliminated with no sacrifice in weight. Several of these small drag reductions added together can thus produce a sizable saving in drag. In every case, the final design will evolve as a compromise between the reduction in drag and the increase in weight.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., June 9, 1954.

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EFFECT OF PARASITE DRAG ON PERFORMANCE
GROSS WT. = 10,000 LB; $\Omega R = 500$ FPS; $\sigma = 0.07$; DISK LOADING = 2.5 LB/SQ FT

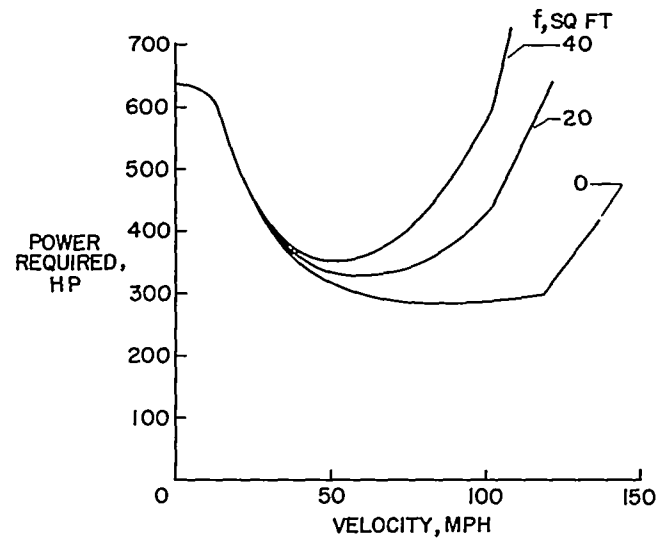


Figure 1

TYPICAL HELICOPTER LANDING GEAR INSTALLATIONS

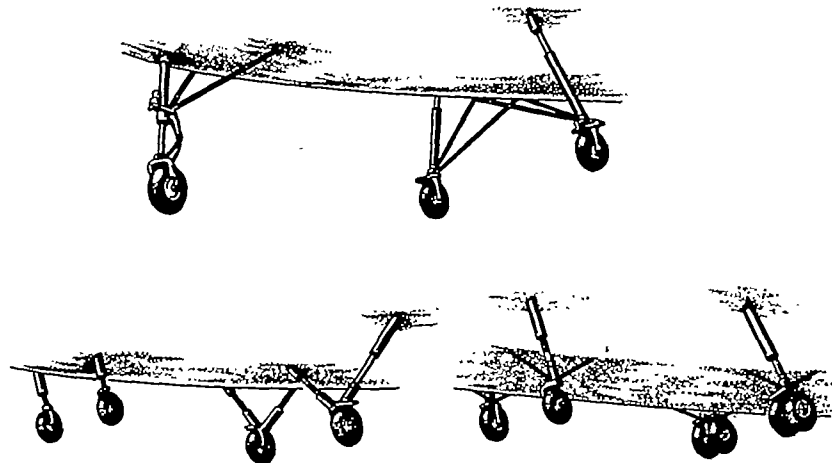
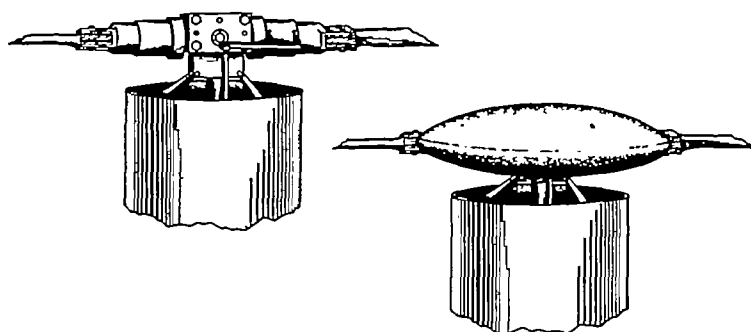


Figure 2

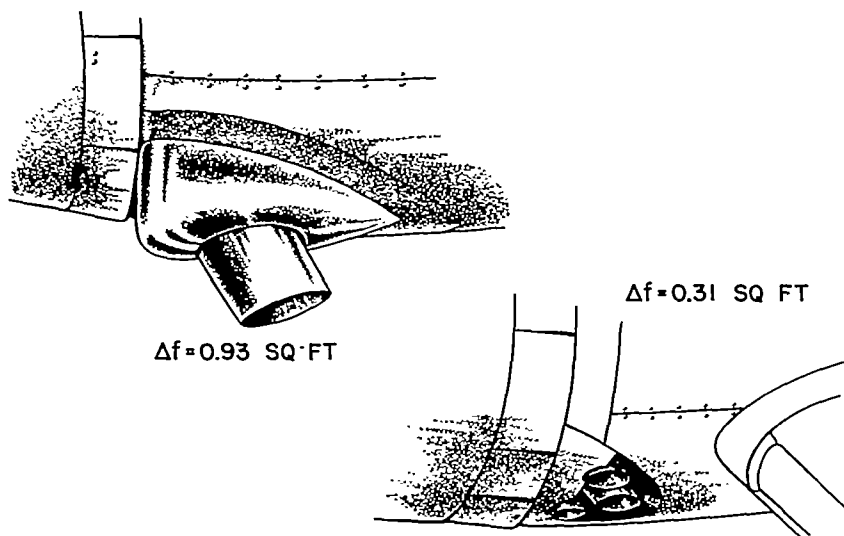
EFFECT OF FAIRING ON HUB PARASITE DRAG



$$\Delta f = 1.2 \text{ SQ FT}$$

Figure 3

TYPICAL RADIAL-ENGINE EXHAUST-STACK INSTALLATIONS



$$\Delta f = 0.93 \text{ SQ FT}$$

$$\Delta f = 0.31 \text{ SQ FT}$$

Figure 4